Nanodosimetric characteristic of carbon ion beam– experiments and Monte Carlo simulations

Marcin Jan Pietrzak

The goal of the study is nanodosimetric research on carbon ions using experimental and theoretical approaches. The basic experimental setup used in the study is the Jet Counter nanodosemeter, which is based on the principle of counting single ions formed by ionising particles in a millimetre volume of low-density gas. The volume is a model for a biological target comparable in size to a short segment of a DNA strand.

The work presents new techniques and concepts regarding both nanodosimetric measurements and data analysis regarding experiments on accelerator-based sources of light ions. The Jet Counter device has been installed at the accelerator beamline in the Heavy Ion Laboratory, University of Warsaw, where it was used to measure the ionisation clusters produced by carbon ions with kinetic energies ranging from 12 MeV to 84 MeV. Additional tests were performed using ^{241}Am Americium source of α particles. To complement the measurements, a numerical model of the Jet Counter was created using the Geant4-DNA Monte Carlo toolkit.

New methods of analysis based on Generalised Poisson Distribution (GPD) as the model of Ionisation Cluster Size Distribution (ICSD) are presented in this work for the first time. This includes the unfolding procedure of the Detector Response Function (DRF) as well as a possibility to utilise data from multi-projectile events usually considered useless pile-ups.

A novel technique of two-target nanodosimetric measurements is devised and applied, resulting in the first presentation of two-dimensional ICSDs. The technique allows for the studies of the spatial correlation of the creation of ionisation clusters in two neighbouring nanometric targets.

Besides obtaining results for different experimental conditions, new data allowed for the test of some Jet Counter features, like the gas jet's speed and the target's homogeneity, that had not previously been verified.

Also, a novel approach is proposed regarding the interpretation of the ICSDs in nanometric volumes in terms of the probability of initial radiation damage. With the new approach, a nanodosimetric measurement can be seen as a correct model of radiation-induced damage to the DNA.